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ABSTRACT

This study employed a 2x2 (Generative Activities by Navigational Activities) post-test only research design in examining learning while using a hypertext system in a linear, navigational, linear generative, or navigational generative format. Participants were 43 undergraduate students. In the first experiment, participants were assigned to one of the four conditions and expected to learn the information to solve a posed problem, while students in the second experiment learned the information to pass a reading comprehension test. Results from the first experiment revealed that students in the navigational condition outperformed those in the linear condition with respect to their problem solving score. While there was no significant difference between generative and non-generative conditions, the study found that there was an interaction indicating that generative activity may inhibit navigational hypertext systems in problem solving. The second experiment revealed significant differences between generative and non-generative conditions. While no significant difference between linear and navigational conditions with respect to reading comprehension scores was found, learners' reading comprehension raw score and dwell time revealed that learners assigned the linear conditions outperformed those assigned navigational conditions; this effect was canceled by dwell time in the final analysis. In both experiments the computerized text used was identical. (Contains 44 references.) (MES)

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The Effects of Goal Intentions on Problem Solving and Reading Comprehension in Generative Hypertext Processing

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Introduction

The study employed a 2 x 2 (Generative Activities by Navigational Activities) post-test only research design in examining learning while using a hypertext system in a linear, navigational, linear generative or navigational generative format. In Experiment One, participants were assigned one of the four conditions and expected to learn the information to solve a posed problem, while students in Experiment Two learned the information to pass a reading comprehension test. Results from Experiment One revealed that students in navigational condition outperformed those in linear condition with respect to their problem solving score. While there was no significant difference between generative and non-generative conditions, the study found that there was an interaction term indicating that generative activity may inhibit navigational hypertext system in problem solving. In contrary to Experiment One results from Experiment Two revealed significant difference between generative and non-generative conditions. While no significant difference between linear and navigational conditions with respect to their reading comprehension scores was found, a closer look at the learners' reading comprehension raw score and their dwell time revealed that learners assigned linear conditions outperformed those assigned navigational conditions but this effect was wiped out by their dwell time in the final analysis. In both experiments the computerized text used was identical.

Generative Learning

In Wittrock's (1974, 1978) generative model, he examined how learners used background knowledge to construct meaning from stimuli. Learners are not passively but are actively engaged in the construction of meaning as it relates to their beliefs, experiences, current goals, and the context in which learning occurs. Linden and Wittrock (1981) found that students who were instructed to generate associations for text showed greater comprehension and fact retention than those who were taught using conventional reading instruction. Doctorow, Wittrock and Marks (1978) showed that students who generated paragraph summaries significantly increased their retention and comprehension of the text compared to control groups who did not generate summaries. Studies in traditional text processing also found that encouraging students to generate elaborated explanatory answers about new content increases learning (Pressley et al., 1992). Generative and elaboration strategies have been shown to be effective while learning from text in general (Pressley & Ghatala, 1990; Pressley et al., 1992; Wittrock, 1974, 1978, 1989). Their application to hypertext systems, where learners already have many task requirements (i.e., navigational choices and different goals), has not been evaluated. The results of the study by Barab, Young & Wang (in press) indicated that there was a positive correlation between generative activities produced and the reading comprehension scores. The design of their study (Barab et al, in press) did not separate the navigational capabilities from generative activities, because both conditions afforded navigational control; therefore it is still unclear if the generative system would differentially benefit readers with problem solving and reading comprehension goals for reading.

In working with generative hypertext, the text is being altered as is the reader's understanding of the information contained in the text. This has much in common with research in ecological psychology, defining cognition as a process of a dynamic interaction in which neither the environment nor the organism is the only primary cause. The literature on situated cognition contends that meaning is constructed as an ongoing interaction between a perceiving/acting agent and an information-rich environment (Clancey & Roschelle, 1993; Dent, 1990; Gibson, 1986; Greeno, 1989; Young, 1993; Young & McNeese, 1995). Organisms and their environments define and shape each other in the process of interaction. Thus the learners' goals and intentions define and are defined by the situation in which the information is learned. As such, the interaction of individual's goals for reading and the situational constraints contribute to how the information is perceived and learned (Greeno, Smith & Moore, 1993; Young, 1993). One cannot exist without the other. Taking this view leads to an emphasis of understanding as an unfolding process in which information is "picked up" (Gibson, 1986) from the text as a result of the interaction between each reader's current intentions and the affordances provided by the current text. Learning is viewed as an

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active process in which students modify and reorganize knowledge while they are learning, rather than as a passive process where learners are viewed as receptacles of knowledge (Greeno, 1989). Hypertext in generative format affords students more opportunities to become actively involved with information than do non-interactive environments. These interactive environments also encourage the concept of "mindful engagement". Salomon et al. (1987, 1991) discussed that although computer tools offer a partnership with the potential of extending the user's intellectual performance, the degree to which this potential is realized greatly depends on the user's mindful engagement. The introduction of contrived problems can help focus or anchor learning in environments requiring large amounts of learner control, by constraining navigation toward those aspects of the hypermedia that are consistent with the posed problem. The potential benefits are mediated by learner goals for using the hypertext (Barab, Bowdish, Young & Owen, 1996; Barab, 1997).

Learner Control and Program Control

In spite of the theoretical appeal of hypertext learning environments, empirical findings yield mixed results with respect to the learning benefits of learner navigational control over programmed linear control of instruction (Goforth, 1994; Kinzie & Sullivan, 1989; Niemiec et al., 1996; Steinberg, 1989). Although some studies have found increased benefits of navigationally controlled instruction (Gray, 1987; Hannafin & Sullivan, 1996; Kinzie, Sullivan, & Berdel, 1988), others have found that students with high degrees of learner control performed less effectively than those receiving program control (Pollock & Sullivan, 1990; Ross & Rakow, 1981). When one examines these isolated studies, there appear to be results showing both advantages (Gray, 1987; Hannafin & Sullivan, 1996; Kinzie et al., 1988) and disadvantages (Pollock & Sullivan, 1990; Ross & Rakow, 1981) of learner navigational control opposed to programmed linear control. Lawless and Kulikowich (1996), examining hypermedia navigation as well as achievement and attitudinal measures, found that some students benefited from increased learner control while others appeared lost, confused, or even apathetic. Still others have credited differences to prior knowledge finding that increased learner control appears to be useful for more knowledgeable learners (Shyu & Brown, 1995).

With the development of multimedia technology and World Wide Web, computer-based non-linear text has been made multi-dimensional by including not only text-based information but also images, audio and video clips. Reading hypertext allows readers to interact with the text, to make decisions about both what information to access and sequencing of this information (Landow, 1992; Carver, Lehrer, Connell & Erickson, 1992). These features of hypertext have drawn much attention from both researchers and educators (Barab, Bowdish, & Lawless, 1997; Gall & Hannafin, 1994; Heller, 1990; Landow, 1992; Nielson, 1990; Spiro & Jehng, 1990) but little attention has been given to the other type of hypertext which is referred to as generative hypertext (Barab et al, in press; Young, Barab, & Wang, 1997) based on the works of Wittrock (1989). Unlike reading traditional hypertext, reading generative hypertext requires readers to adopt a more active role in reading and become readers/authors (Barab et al, in press & Young et al, 1997). This type of hypertext format not only allows learners to make decisions about what information to access, sequencing of information, and control the pace, but also to change the actual document by engaging in generative activities while reading, thereby creating their own unique text. This type of open-ended activity afforded by the generative hypertext can encourage readers to be more mindfully engaged. (Salomon & Globerson, 1987; Salomon, Perkins & Globerson 1991). Although the benefits of mindful engagement in learning are appealing, little empirical evidence is available for its effect in the context of computer-based generative hypertext.

Predicted on the research related to the advantages of providing students with a problem focus (Anderson et al., 1994, Barab, et al., 1996, CTGV, 1990) and advantages of instructing students to generate associations for text (Linden & Wittrock, 1981) we sought to test this in two separate experiments: First, when readers had a specific problem-solving goal in mind for reading and second when their goal was simply to comprehend the text in the context of preparing for a traditional test of reading comprehension. We designed a generative form of the Nigeria hypertext which provides two Navigational activities (Linear vs. Navigational) and two Generative activities (Generative vs. Non-generative) in this study. We were specifically interested in comparing students' problem solving and reading comprehension abilities when information about Nigeria was presented as: 1) Nigeria Hypertext in linear format; 2) Nigeria Hypertext in linear and generative format; 3) Nigeria Hypertext in navigational format; 4) Nigeria Hypertext in navigational and generative format. We hypothesized that generative activity would benefit reading comprehension due to their active processing while reading and navigational activity would benefit problem solving. We also hypothesized that linear condition would benefit reading comprehension while generative activity would benefit linear hypertext system.

In Experiment One, students were assigned one of the four conditions and expected to learn the information to solve a posed problem. In Experiment Two, students were assigned one of the four conditions with the expectation of learning the information to pass a reading comprehension test. Dependent measures included a questionnaire assessing students' problem-solving success (Experiment One) and reading comprehension (Experiment Two). Efficiency measure was calculated for both reading comprehension and problem solving scores to control time spent with the hypertext (dwell time) given previous findings demonstrating significant correlation's between dwell time on hypertext learning and outcome scores. Items of dependent measures were developed to address the issue of

achievement. Therefore, items were not measuring one particular construct. Specific research questions of this study are:

1. Were there any significant differences among the students assigned the Navigational conditions (linear vs. non-linear), Generative conditions (generative vs. non-generative) with respect to their problem solving scores? (Experiment One); and
2. Were there any significant differences among students assigned Navigational conditions (linear vs. navigational) and Generative conditions (generative vs. non-generative) with respect to their reading comprehension scores? (Experiment Two).

Experiment One

Methods

Participants

43 undergraduate students were recruited from a Northeast University. Before the experiment, each participant completed a consent form. All participants received two extra course points toward their course grade for their participation. Participants include 6 males and 37 females. They were randomly assigned to one of the four conditions.

Computerized Lesson

The instructional lesson used in this study was a social studies lesson about Nigeria which was modified from its previous version (Barab et al, in press) programmed using Hypercard™. The lesson was run under four conditions (linear vs. navigational, generative vs. non-generative) on Macintosh personal computers. This computerized lesson contains approximately 70 megabytes of information, including 25 single-spaced pages of textual information, 22 digitized images, and 5 digitized video clips. All the content is adapted from four high school textbooks, two articles from the Nigerian consulate, one articles from the journal *Face* (1998) and current information retrieved from the World Wide Web. All information has been reviewed for accuracy and completeness by two native Nigerians: a Nigerian graduate student majoring in African history and a Nigerian undergraduate majoring in Education. The content of the treatment material remained the same in all four conditions in both experiments. However, to establish a problem solving goal in experiment One participants viewed a short digitized video clip suggesting that there was an untreatable virus currently plaguing Nigeria. Although the area of Nigeria where the virus began was unknown, there was patient data available on six patients that could be used to determine the origin of the virus in hopes of locating the host and developing an antibody. However, these files only provide general descriptions of each patient's background that, when matched with the correct ethnic group, could be used to predict the area of Nigeria where the virus most likely originated. Some of the information was related to the patient profiles and can be used to predict the source of the virus, while other information was related to other aspects of Nigeria.

Problem Solving Score

A problem solving score was calculated from learners' determination of the ethnic group of all six patients and their inference that since four of the six patients were Hausa, the virus most likely began in the north of Nigeria where most Hausa people live. Students were given one point for each patient correctly identified and 2 points for the overall choice of North, where four of the six patients came from, with a total score of 8 points.

Procedure

All recruited participants were screened for students with high prior knowledge of Nigeria. Virtually nothing was known about Nigeria by all participants of this study. The control of prior knowledge was dropped out of the analysis. Treatment conditions were randomly assigned to participants in both experiments and they were told that the lesson was designed to help instructional designers to develop effective educational software and would take about 30 minutes. All participants were given a brief computer-based tutorial concerning the skills necessary to use the software. Participants were instructed to click on a particular button depending on which condition they were assigned. To pose a problem solving context, participants at this point watched digitized video clips in which the problem was introduced. While participants made navigational choices, the computer program generated a log file to maintain a continuous record of time they spent on each node, their navigational path, their personal journal notes, card headings generated, naming of geographical and ethnic maps. After completing the computer-based section of the experiment, students completed their problem-solving responses or a reading comprehension questionnaire depending on which experiment they were assigned. The log file data were examined to determine the total time each participant spent studying the lesson and was used to calculate efficiency measure to control for dwell time on the computerized lesson. The efficiency measures of reading comprehension and problem solving was calculated by summing up the number of correct answers divided by the total time and then multiplied by 1000 to give whole-number values.

Results

One participant was identified as a Native Nigerian and was dropped out of the analysis. The total number of participants in the study was 43. Randomized assignment was ensured by the design of the study, so the preliminary analyses focused on screening data to ensure the accuracy of data entry and evaluation of sample distribution, linearity and normality of the scales used in this study. No univariate outliner (standardized score > 2.5) was found after the evaluation of the statistical assumptions but the evaluation revealed non-normality of the outcome variable (problem solving efficiency score). Statistical transformation suggested by Tabachnick & Fidell (1996) was performed to stabilize the variance of the outcome variable.

The results of the Analysis of Variance disclosed that there was a significant difference between the two navigational activities (Linear vs. Navigational) with the navigational activity demonstrating superior problem solving efficiency score ($F=20.459$, $p<.001$). Although there was no significant difference between generative and non-generative conditions, there was a significant interaction among the navigational activities and the generative activities ($F=4.124$, $p<.05$), which indicates that generative activities interfered learners when they were given more freedom to navigate to solve a problem.

Experiment Two

Methods

Participants

44 undergraduate students were recruited from a Northeast Land Granted University in this study. Before the experiment, each participant completed a consent form. All participants received two extra course points toward their course grade for their participation. Participants include 12 females and 32 females. They were randomly assigned to one of the four conditions.

Computerized Lesson

The same instructional lesson used in this experiment as in Experiment One. However, instead of watching the video clip which was used to introduce the problem in Experiment One, participants were instructed to learn the information in preparation for a set of reading comprehension questions. All other information in the four conditions was identical.

Reading Comprehension Measure

The reading comprehension measure focused on factual information derived explicitly from the computerized lesson. The scale was designed to measure retention and recall of the factual information directly related to the social studies lesson. The Scale was composed of blank fill-in items with a total of 30 blanks. They were created from content that spans all the cards in the computerized social studies lesson and have been reviewed by a content expert (a high-school history teacher), two educational psychologists and one doctoral graduate student. Data collected from the previous study (Barab et al, in press) have been used to perform item analysis of the reading comprehension scale. Items that had a correct response rate above 95% or below 5% were removed, so the final pool of items is reduced to 22 items. The overall score for the reading comprehension measures were calculated by adding up the number of correct responses (29), with a maximum score of 29 points.

Procedure

Procedures were identical to Experiment One, except that after they completed the program they filled out a reading comprehension questionnaire. The log file data were examined to determine the total time each participant spent studying the lesson and was used to calculate efficiency measure to control for dwell time on the computerized lesson as discussed in Experiment One.

Results

One case was dropped out of the analysis because of incomplete data set due to computer program crash in the experiment. The total number of participants in the study was 44. Randomized assignment was ensured by the design of the study, so the preliminary analyses focused on screening data to ensure the accuracy of data entry and evaluation of sample distribution, linearity, and normality of the scales used in this study. The evaluation of the statistical assumptions found 1 univariate outlier (standardized score > 2.5). It was removed from the analysis. The evaluation also revealed non-normality of the outcome variable (reading comprehension efficiency score) statistical transformation suggested by Tabachnick & Fidell (1996) was performed to stabilize the variance of the outcome variable. The total cases included in the final analysis were 43.

The results of the Analysis of Variance revealed that there was a significant difference between the two Generative activities (Generative vs. Non-generative) with generative activities help improving reading comprehension significantly ($F=5.029$, $p<.05$). There was no significant difference between Navigational activities

(Navigational vs. Linear) while reading and no interaction term among the two navigation activities and two generative activities was found.

Discussion

The results of this study suggest that increased levels of learner control are beneficial when individuals are using a hypertext program to solve a specific problem. In this study, individuals who were free to navigate directly to those cards of information they deemed appropriate did significantly better at the problem-solving task than those who proceeded through the document in a linear manner. This finding is consistent with the findings in Barab et al's study (in press). While there was no significant difference between students assigned the Linear Non-generative Condition and Linear Generative Condition, students assigned Navigational Generative condition did not do well on problem solving comparing with those assigned Navigational Non-generative condition. This finding indicates that generative activities in general may benefit learning (reading comprehension) but may inhibit navigational hypertext when learners are engaged in problem solving. Generative activities may produce interference with respect to their navigational choice and sequencing of text. When navigating through the hypertext to solve a problem has already posed considerable difficulties, the addition of generative activities proves to be a distraction and an overwhelming burden in problem solving.

In contrast to the results of Experiment One on problem-solving scores, we found that students assigned the Generative condition outperformed those assigned the Non-generative condition. We had expected that individuals assigned the Linear condition would do better than those assigned the Navigational condition. While it was true, the analysis failed to reach a statistical significance level. A close look at the raw reading comprehension score (reading comprehension score before being converted into efficient score) revealed that learners assigned linear condition outperformed those assigned navigational condition ($F = 4.745$, $P < .05$). This finding indicates that when students' raw reading comprehension scores were converted into efficient score (raw score/dwell time), their dwell time wiped out most of the effect (see table 1 below). They had high reading comprehension score but were not efficient because they spend more time and therefore they reviewed significant number of facts.

Table 1. Means and Standard Deviations of Dwell Time and Raw Reading Comprehension Score by Students in the Two Conditions Using Hypertext for Reading Comprehension Test

CONDITIONS	Dwell Time (minutes)		Raw Score	
	M	SD	M	SD
Linear Condition	36.89	12.52	20.02	4.91
Navigational Condition	28.18	11.87	16.44	5.04

Conclusion and Implications

In this study we examined students' problem solving and reading comprehension when using text in linear, navigational, linear generative or navigational generative hypertext system to solve a problem or to prepare for a reading comprehension test. The results support the driving force of learners' goals, whether implicit in the educational setting (e.g., studying for a test) or adopted from a contrived context (e.g., anchored instruction or problem-based learning), in co-determining the learning context. Understanding students' goals in turn explains the outcomes of instruction, the effects of instructional designs (e.g., learner control/program control). Further the study also provides empirical evidence regarding which formats may best be used to teach students problem solving and/or comprehension skills. For example, students with problem solving goals who used the Navigational hypertext system outperformed those students assigned the Linear conditions. However, when students had reading comprehension goals, students using Generative hypertext system outperformed those using Non-generative hypertext system. We did not find significant difference between linear and navigational activities with respect to reading comprehension, being a finding that could be attributed to the effect of dwell time. Although we are still not sure why generative activities did not benefit learning overall we did find that generative activities hurt learners when they were given more freedom to navigate to solve a posed problem.

Given the size and complexity of many hypertext environments that students are expected to use (e.g., the World Wide Web, CD-ROMs), it is imperative that educators consider the goals that students have for engaging in these environments. Educators exercise some control over the goals that students adopt by creating a context in which students read for a test or read to complete some performance-based assignment such as problem solving. In so doing, they must recognize that materials optimized for some goals (e.g., information search and retrieval) may be distracting and clumsy for others (e.g., reading comprehension). This is consistent with the theories of situated cognition and ecological psychology in which it is posited that different learner goals establish different learning contexts, which may or may not couple the learner and environment. While the literature on both generative activity and learner control does not lead to a clear conclusion regarding the usefulness of learner control as an instructional

strategy and generative activity as a format of hypertext, the explanation may lie in the goals that users adopt for learning. This study provided some empirical evidence that learner's goals must be understood to fully explain the interaction of student with instruction. This study found that learners in the Generative condition who had reading comprehension goal outperformed those assigned the Non-generative condition. Learners with problem-solving goals scored higher on a problem-solving measure than did learners with less control. Such a difference was true but was not significant when learners had reading comprehension goals. This finding is of interest; especially when their reading efficiency score is taken into consideration. Future research needs to continue to explore the interaction of goals and instructional context, especially with respect to the instructional activities that require more mindful engagement, such as reading comprehension test focus on inferential information rather than factual information.

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